



**Statement of Dr. Arun Majumdar, Director  
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U.S. Department of Energy  
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Committee on Appropriations  
U.S. House of Representatives  
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*ARPA-E: Catalyzing Energy Breakthroughs to Secure America's Future*

Chairman Frelinghuysen, Representative Pastor, distinguished members of the subcommittee, thank you for the opportunity to testify today on behalf of the Advanced Research Projects Agency-Energy (ARPA-E) for the Fiscal Year 2012 Budget request of \$650 million.

I want to start on a historical note. On February 12, 1958, President Eisenhower signed Public Law 85-325, authorizing the creation of the Defense Advanced Research Projects Agency (DARPA). This was in response to the launch of Sputnik and to a realization that the U.S. had lost its technological lead and its future security was at stake. DARPA has since been responsible for the development of many transformational technologies, such as the precursors to the internet, stealth and GPS. In 1962, DARPA appeared in its first appropriation bill, and the 87<sup>th</sup> Congress that voted for it became a part of our history of innovation. As the President has said, today the U.S. faces a new Sputnik-like moment. Our future depends on three securities: national security, economic security and environmental security. At the foundation of all these securities are innovations in energy technologies that would reduce our dependence on foreign oil, provide clean and inexpensive electricity, and create a secure, efficient and sustainable infrastructure. As the first Director of ARPA-E, I am grateful for the opportunity to play some role in the creation of a secure American future.

ARPA-E can play a role in protecting America's national security. As a country, we import more than 50 percent of oil and export about \$400 billion per year (about \$1 billion per day), a sizeable portion of our trade deficit. The recent oil price spikes due to turmoil in the Middle East highlights just how vulnerable we are to even short-term instabilities around the world. This is not sustainable in the long-term. We must create a diverse portfolio of sustainable options for transportation and mobility based on domestic resources to decrease the burden of oil imports. That requires innovations in energy technologies. We also need to reduce the cost of electricity from clean and sustainable sources (clean coal, nuclear, natural gas, solar, wind, geothermal etc) so that energy is affordable to Americans and our businesses are enabled to power the economy.



ARPA-E can also help ensure America's economic security. Income levels are rising in the world and the world needs more energy. Every nation in the world wants to use sustainable and clean energy. Unfortunately, the technologies that are needed in the future do not exist today. If we are to win the future, we need to use our American ingenuity and technological leadership to invent affordable clean energy technologies, make them locally, and sell them globally, just as we did in information technology and biotechnology. This offers an important global business opportunity for the USA. We have a window of opportunity and we need to grab it; speed is of the essence.

ARPA-E focuses exclusively on breakthrough technologies promising genuine transformation in the ways we generate, store, distribute and utilize energy. If just a fraction of the projects funded by ARPA-E are successful, the U.S. will benefit greatly by creating new industries and jobs, making energy technologies substantially more cost-saving, profitable, and cleaner in a sustainable way.

#### Early Successes in Technology Innovations

How does ARPA-E measure success? ARPA-E enables the nation's pioneers and entrepreneurs to innovate breakthrough technologies that do not exist yet today – but if they did, they would make today's technologies obsolete and create large commercial markets. For example, ARPA-E has invested in a portfolio of ideas on rechargeable batteries that would make electric cars have longer range and lower lifecycle cost than gasoline-based cars so that electric vehicles can scale without subsidies and significantly reduce our dependence on imported petroleum. Today's lithium ion battery is inadequate and no one else in the world has this future battery. The global race is on. ARPA-E is focused on identifying the opportunity and creating a competition among innovators. The portfolio of ideas that ARPA-E funds are too risky for the private sector to invest in at this time. However, if one of the ARPA-E ideas is shown to be practical, it could indeed change the world. But transformations do not happen overnight – it will take at least 10-15 years to scale these technologies in cost and volume, and indeed change the world. In the process, many of these ideas will fail and ARPA-E will let the market pick the winners.

In the next 3-5 years, we can only look for indicators of success: (1) Are we attracting the best minds to energy R&D? Are we getting the best ideas? (2) How many small businesses have been created? (3) Do we have the world's best performance? (4) How many patents have been filed and licensed? (5) If ARPA-E's funding has created value, how much follow-on funding has the private sector made?

We are seeing some initial early signs of success. I am happy to report that six projects funded by ARPA-E received \$24M in 2010. These small investments allowed



these innovators to do the research and overcome some serious technical barriers, ahead of schedule. Only when this happened, the private sector realized the value of these innovations and invested more than \$100M in only one year. In addition, we have seen 17 patents filed. While we are still in the early stages, these are good signs for future success.

### ARPA-E Operational Success – Institutionalizing a Sense of Fierce Urgency

In order to win the future in a globally competitive world, speed is of essence. Since ARPA-E demands speed from the innovator community, I strongly feel that the community and you should demand speed and urgency of ARPA-E. ARPA-E is administered in ways that enable the agency to be lean, effective, and agile. ARPA-E strives to be a model of excellence for a small agency. In its short existence of less than two years, ARPA-E has implemented several key business process innovations that have earned it recognition as an organization to emulate.

We have streamlined the operations within ARPA-E to introduce unprecedented levels of speed and efficiency. ARPA-E has created a 5-Es process for program creation and management:

- (1) *Envision* a new opportunity for a program and do background in-house research;
- (2) *Engage* the experts from the technical community for stakeholder input, an internal debate about reasons for creating a new program, and the announce a new program and receive proposals;
- (3) *Evaluate* the proposals based on merit-based technical peer review;
- (4) *Establish* the program by selecting and contracting multiple awards;
- (5) *Execute* the program by active hands-on project management by ARPA-E program directors for proper stewardship of taxpayer dollars (see later).

This process has not only increased the speed and efficiency but has also improved the quality of the reviews and project management. The total process from conception of a new program to contracting awards (first 4 Es) takes 6-8 months, with contracting down to just 2-3 months. ARPA-E achieves this by utilizing a program development process that includes extensive up-front technical research and technical workshops co-hosted with other DOE program offices, and technical community members. ARPA-E also employs a thorough merit-based peer review process. Further, ARPA-E has embedded dedicated procurement and legal teams, allowing ARPA-E to achieve exceptional speed and efficiency for processing awards from announcement to signing contracts. This speed, efficiency and transparency are critical for our government, and that is exactly what ARPA-E is doing. You could call ARPA-E the “urgency agency.”



As noted in a report from the President's Council of Advisers in Science and Technology (2010), "Although the ultimate success of the research funded by ARPA-E is unknown... they have been successful in their peer review of proposals, quick negotiation of contracts, and rapid hiring of high-caliber personnel."

The success of these technologies depends not only on the scientists, engineers and entrepreneurs that we fund, but also on the program directors we have hired. Most anticipate that they will stay at ARPA-E only for a maximum term of 3-4 years. But while they are here, our program directors are involved in active project management and are literally part of the teams they are funding to help them speed up the process of innovation. They have a fierce sense of urgency, and they are demanding speed from our teams.

Technical flexibility, speed, agility and empowerment of Program Directors are the key aspects of ARPA-E's programs. For example, the emerging importance of rare earth metals in the energy sector has been highlighted by the mismatch between the rapidly growing demand relative to the limited global supply. ARPA-E was able to rapidly respond to this pressing problem and arranged a workshop in December 2010 to bring together thought-leaders from across scientific and engineering disciplines to identify transformational, early-stage applied research and development approaches to address the technical challenges related to the potentially limited availability of rare earth metals and critical materials in the energy sector.

#### ARPA-E and National Security – Partnership with Department of Defense

Building on an already strong cooperation between the U.S. Department of Energy and the U.S. Department of Defense on national security issues, the U.S. Secretary of the Navy, Ray Mabus, recently announced at the ARPA-E Energy Innovation Summit a new partnership between ARPA-E and the Department of Defense to jointly develop energy technologies that will be use to make our nation and our armed forces secure. This partnership will be initiated during the 2012 fiscal year. The Department of Defense's Office of the Assistant Secretary of Defense for Research & Engineering (ASDR&E) aims to take advantage of early technology breakthroughs funded through ARPA-E. In particular, using ARPA-E's technical expertise in grid scale energy storage, batteries for electric vehicles, and power electronics, ASDR&E plans to develop hybrid energy storage systems that will provide future defense systems with long duration storage suitable for a variety of applications, including military bases and mobile units.

Cost effective energy storage is also of interest to DOD's Installations and Environment office, which will work with ARPA-E to assess the technology requirements for storage across military installations. Vulnerability to energy supply



disruption is a significant challenge for facilities dependent on the commercial power grid, and backup power is both limited and expensive. Onsite renewable electricity generation combined with grid scale storage would allow installations to maintain critical functions in the event of grid disruption and enhance installations' efforts to develop micro-grids for energy security.

ARPA-E is continuing its discussion with the DoD to build upon these partnerships and create other ones where innovations in clean energy technologies would make our nation secure.

### ARPA-E Energy Innovation Summit

ARPA-E recently hosted its second annual Energy Innovation Summit. We were able to attract our nation's best energy innovators from industry, academia and government; the Summit had over 2,000 registered participants spanning all stakeholder communities, including scientists and engineers, entrepreneurs, small and large business CEOs and CTOs, technology investors from the venture community and investment banks, policy researchers and NGOs. A key feature of the Summit is the technology showcase, where ARPA-E showcases not only the technologies that it invested in, but also showcases other promising technologies. The goal is to ensure that America wins the future, not just the ARPA-E technologies.

The Summit also brought together as speakers and panelists an incredible lineup of energy thought leaders from around the country, including Arnold Schwarzenegger, former governor of California, Chad Holliday, former Chairman & CEO, DuPont; Chairman, *Bank of America*, Ray Mabus, Secretary of the Navy, Senators Lisa Murkowski, Lamar Alexander and Mark Udall, Congressman Steve Israel, as well as Secretary Chu and senior leadership from DOE and the White House. We intend to host another Summit in 2012 and we hope you will join us next year.

Last year at the hearing, your committee made a recommendation that since last year's Summit was so successful that ARPA-E should consider organizing mini-Summits around the country to bring the local innovation ecosystem together. I am pleased to report that we have indeed followed up and organized a mini-Summit in Arizona that was very successful. We hope to do a few more in the future and I look forward to working with you in this regard.

### Uniqueness of ARPA-E Programs and Projects

ARPA-E enables the nation's pioneers and entrepreneurs to innovate technologies that do not exist yet today – but if they did, they would make today's technologies





obsolete and create large commercial markets. ARPA-E does not focus on exploratory science, but instead on translating the science into breakthrough technologies that are too risky and early-stage for private sector investment. The goal is identify opportunities and develop those energy technologies that establish entirely new learning curves to make our nation secure and clean energy affordable and sustainable.

ARPA-E programs generally fall into two categories:

- *Translating New Areas of Science into Technology*—for example, ARPA-E’s current Electrofuels program. In contrast to today’s biofuels (based on algae, sugarcane, corn or cellulose) that use photosynthesis, the goal of the Electrofuels program is to create a biological, non-photosynthetic process to produce liquid fuels. This is an entirely new way of creating biofuels that is potentially more than 10 times more efficient than today’s biofuels, which could potentially mitigate the problems of land and water use. This approach is not being done anywhere else.
- *Creating a Quantum Leap in Technology* —for example, ARPA-E’s current program called Batteries for Electrical Energy Storage in Transportation, or BEEST. While DOE and most outside R&D is focused on lithium-ion batteries, ARPA-E is looking for other battery chemistries, such as Zinc and Magnesium, that, if successful, would yield batteries that are less expensive and provide longer range vehicles than today’s approaches based on lithium-ion batteries.

Please note that ARPA-E identifies the opportunity and creates a competition. In its solicitations, ARPA-E provides cost and performance metrics for projects to meet or beat, and does not prescribe the method up front, i.e. it is technology agnostic. ARPA-E funds a portfolio of competitive approaches and then seeks to let the scientific competition play out and leave it to the private sector to pick which technologies will be commercialized.

ARPA-E proactively seeks out “white spaces” where it can fill a vital gap in early stage research and development; coordination between the Department’s basic research and applied technology programs is a high priority for the Secretary of Energy. For example, ARPA-E has created a Panel of Senior Technical Advisors (PASTA), a group of technical leaders within DOE spanning the Office of Science, the Office of Fossil Energy, the Office of Nuclear Energy, the Office of Energy Efficiency and Renewable Energy, the Office of Electricity Delivery and Energy Reliability, and others from senior DOE leadership positions. The intent of the PASTA meetings is to share information, avoid duplication, and engender coordination, cooperation, and collaboration among all of the DOE research programs. In addition, other DOE programs are involved from beginning to end in ARPA-E’s program development process—providing technical



consultation, co-hosting technical workshops, and serving as reviewers for ARPA-E concept papers and full applications.

ARPA-E's programs and projects to date have included:

- **Electrofuels:** ARPA-E seeks to use microorganisms to harness energy and convert carbon dioxide into liquid fuels. Theoretically, this could be ten times more efficient than current approaches.
- **Batteries for Electrical Energy Storage in Transportation (BEEST):** The goal of the BEEST program is simple: Create a new generation of rechargeable battery technologies that will allow a longer range and lower life-cycle cost than gasoline-based cars, so that electric cars can scale without subsidies.
- **Building Energy Efficiency Through Innovative Thermodevices (BEETIT):** The BEETIT program seeks to develop cost-competitive energy-efficient building cooling technologies that will reduce energy consumption from: (1) overall cooling and (2) refrigerants used in vapor compression systems.
- **Agile Delivery of Electrical Power Technology (ADEPT):** The ADEPT program seeks to create microelectronic circuits that incorporate transistors able to handle high voltages and advanced magnetic materials for much smaller power transformers and inductors. The improved electrical power efficiency from ADEPT could result in smaller personal computers and computer servers, produce lightweight chargers for electric vehicles and allow for the controlled movement of electricity by routing through transmission lines to avoid congestion and overloading.
- **Innovative Materials and Processes for Carbon Capture Technologies (IMPACCT):** IMPACCT is pushing the boundaries of carbon capture research through technologies such as new liquid chemistries that dissolve carbon dioxide and a capture system inspired by jet engines that transforms carbon dioxide from a gas into pellets of dry ice. If successful, the IMPACCT program will allow the continued use of America's coal-based power infrastructure without further increases in carbon dioxide emissions.



- Grid-Scale Rampable Intermittent Dispatchable Storage (GRIDS): The GRIDS program seeks to develop new technologies that enable widespread use of cost-effective grid-scale energy storage.

### 2012 Programs –Potential Topics

The following five broad thematic strategic direction areas are areas of technical interest that ARPA-E plans to explore in FY 2012.

**Transportation Systems:** Broadly speaking, reduction in imported petroleum is critical for our national and economic security. ARPA-E will continue to invest in the transportation sector, in both alternative domestic sources of sustainable fuels and electrification of vehicles.

Some broad goals follow:

- Development of those batteries and systems that would make electric vehicles have a range of 300-500 miles and be less expensive than cars based on internal combustion engines. This would enable electric vehicles to be market competitive without government subsidies.
- Development of sustainable and market-competitive transportation fuels using domestic resources such as natural gas or a combination of carbon dioxide and hydrogen, that have 5-10 times less land and water use than that of biomass or algae based biofuels. This would be especially attractive for long-haul trucks and air transport where electrification is unlikely to make an impact.
- Novel uses of information technology to reduce fuel consumption, avoid traffic congestion, and optimize use of existing transportation resources.
- Novel cost-effective power generation or propulsion systems that have significantly higher efficiency than today's internal combustion engines, and thereby maximize the use of transportation fuels.

**Stationary Power:** ARPA-E's goal is to create a diverse portfolio of technological options for low-cost clean electricity from traditional and renewable sources. This will make the U.S. the world leader in these technologies and thereby lead to economic prosperity and American jobs. The broad goals include:

- Electricity generation from solar, wind, natural gas, nuclear, clean coal and other sources to meet base load and peak power at levelized cost of electricity of 5-6 cents/kWh.





- Integrated energy supply systems for distributed supply of heating, cooling, and power in optimal ways.

Given the increasing reliance on an overwhelming percentage of the nation's electricity that comes from stationary power sources, ARPA-E is developing specific future focus areas for programs that employ novel approaches, materials, devices, and processes to make revolutionary advances in the way we capture and utilize energy from a portfolio of diverse renewable and other power sources.

**Electrical Infrastructure:** The U.S. electric grid is undergoing a technical renaissance through the deployment of initial smart-grid technologies. This technical renaissance is motivated by the need to modernize the grid for the 21st century: the U.S. grid is many decades old and often running at maximum capacity, making it vulnerable to outages and security threats.

ARPA-E's goal is to develop next generation technologies that will make today's approaches obsolete, and would truly revolutionize the grid for secure, stable, and reliable transmission and distribution of electrical power and maximize the capacity of today's infrastructure. These technologies could be sold globally, thus leading to American jobs and economic prosperity. Some broad goals are as follows:

- Low-cost electrical storage to increase utilization of renewable resources such as wind and solar.
- Advanced, low-cost and smart components for high-efficiency power transmission, conversion and management at ultrahigh voltages for transmission and medium-to-low voltages for distribution networks.
- Technologies for system-level stability, security, high capacity and reliability for the whole U.S. transmission-distribution system.

**End Use Efficiency:** Energy efficient technologies for buildings, both commercial and residential, offer a tremendous opportunity to reduce energy demand. Buildings consume 40 percent of energy in the U.S., while the industrial sector consumes 30 percent. 72 percent of the nation's electricity and 55 percent of natural gas is used in buildings. The cooling and heating of buildings consumes 40 percent of the total energy used in buildings. This translates into 12 percent primary energy use in the U.S. To date, activities in ARPA-E in energy efficiency have focused mainly on buildings.



ARPA-E will continue to invest in the buildings sector to develop high-efficiency energy technologies, including an expansion of the current BEETIT program and new technologies for energy measurement systems and integrated building operations, as well as a novel way to light a room. This will be coordinated closely with the new Buildings Energy Innovation Hub as well as all the activities in the Office of Energy Efficiency and Renewable Energy.

ARPA-E's goal is to develop those technologies that do not exist today, but if they did they would lead to substantial life-cycle monetary savings by increasing the efficiency of how energy is used in buildings and industry. Some of the program's broad goals include:

- Reduction of energy consumption by 50% with a pay-back period of less than 5 years by highly efficient and smart use of heating, cooling and electrical power in homes and commercial buildings.
- Advanced and alternative technologies to provide industrial goods and services with substantial reduction in energy consumption and a pay-back period of less than 5 years.

**Embedded Efficiency:** On the demand side of our energy economy, energy is consumed primarily in three sectors—buildings, transportation and industry. Buildings consume approximately 40 percent of our primary energy, transportation about 28 percent, and industry about 32 percent. Reduction of energy consumption in the industrial sector is essential to ARPA-E's mission and will be achieved through “embedded efficiency” programs.

ARPA-E's goal is to focus on the industrial sector with the aim to develop cost-competitive technologies and industrial processes to significantly reduce energy consumption and emissions. Some of the program's broad goals include:

- Advanced and alternative technologies to provide industrial goods and services with substantial reduction in energy consumption and a pay-back period of less than 5 years.
- Utilization of waste heat from industry and other uses in intelligent ways to reduce primary energy consumption.

**Wireless Innovation Fund:** The President's Wireless Innovation and Infrastructure Initiative proposes to reallocate a total of 500 megahertz of Federal agency and commercial spectrum bands over the next 10 years in order to increase Americans' access



to wireless broadband. Repurposing spectrum will greatly facilitate access for smart phones, portable computers, and innovative technologies that are on the horizon. This effort will also enhance America's public safety, infrastructure, and competitiveness by investing some of the expected auction receipts in the creation of a broadband network for public safety, expanding access to wireless broadband in rural America, and a Wireless Innovation (WIN) Fund to help develop cutting edge wireless technologies. As part of this initiative, ARPA-E will participate in the WIN Fund by supporting clean energy activities.

An additional \$100 million in mandatory funding is proposed from the Wireless Innovation Fund for ARPA-E to develop cutting-edge wireless technologies. In FY 2012, ARPA-E plans to utilize funds available from the Wireless Innovation Fund on projects related to wireless information technology, as outlined in the detailed justification of the projects section, particularly in Electrical Infrastructure, End Use Efficiency, and Transportation Systems.

**Seedlings/Broad Funding Announcement:** The focus of the Seedlings/Broad Funding Announcement line is to provide funding for innovative projects that happen to fall outside the boundaries of a specific topic area FOAs. ARPA-E believes it is important to capture any truly innovative projects that may be out there and to foster an inclusive community that demonstrates ARPA-E is open to funding projects that are outside of the specific focus topic areas FOAs. In FY 2012, ARPA-E plans to have at least one Broad Funding Announcement.

### Conclusion

ARPA-E's goal is to help catalyze energy breakthroughs with speed and efficiency to secure America's future by attracting the best minds to focus on the major technical challenges in this field and by stimulating technical and the entrepreneurial community to innovate on energy technologies.

